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REINFORCED PLASTER COVERINGS AND BETWEEN-FLOOR CEILINGS

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[Sketches mentioned herein have not been reproduced; a list of captions will be found at the end.]

Structural plaster components, besides possessing low conductivity for heat and sound, have quite a high resistance to fire, and are weather-resistant for an unlimited length of time. For these reasons they are worth calling to the attention of builders, and are being used in wider and wider fields.

Structural plaster components with a volumetric weight of 700-900 kilograms per cubic meter have a coefficient of thermo-conductivity close to that of wood taken across the grain. Repeated tests of the behavior of plaster, under long exposure to burning, and of metal framework covered with it, have shown the very high resistance of this material to fire. A number of authorities have even come to the conclusion that the protection by plaster of metal and other non-fire-resistant constructions is more effective than protection by concrete or brick.

The high resistance to heat of plaster products is explained by the fact that gypsum can be calcined repeatedly. As is known, gypsum semi-hydrate ($CaSO_4 \cdot 0.5H_2O$) obtained by heating at temperatures of from 120° to 180° hardens on contact with water, and is again converted into gypsum dihydrate. The use of plaster in building is based on this property of gypsum.

During calcination, plaster at a temperature of 120° again enters the phase when it absorbs a large quantity of heat, and throughout the whole of the time during which this reaction is taking place, the temperature inside the burning layer is not higher than 160°. The calcination of plaster is started from the surface which is subjected to the influence of high temperatures, and by virtue of the low coefficient of heat conductivity of the material, the heat penetrates rather slowly.

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The weatherproofing power and durability of plaster products has long been proved by practical building, in the same way as the good resistance of plaster has been proved by mechanical means. The Egyptian pyramids, built with a plaster solution, and the most ancient buildings in Central Asia graphically illustrate the immutability of the qualities of plaster with the passage of time.

The great interest in plaster as a building material which has been shown from the beginning of the 20th Century is explained by its innumerable qualities and also by the comparative simplicity of obtaining and preparing it; this has occasioned the wide application of plaster and plaster products in foreign building practice, particularly in the USA.

In 1904, the extraction of gypsum in the USA consisted of only about one million tons per annum, but already in 1923, about five million tons were extracted, about 400,000 tons of which were expended in the preparation of ready-made products for building purposes. The plaster industry in the USA began to develop particularly strongly after 1923, i.e., in a period of far more intensive building. For the past few years plaster products have been completed at a high rate in the USA, particularly reinforced plasters, which have shown their excellent qualities in between-floor ceilings and in the roofing of industrial buildings.

The majority of builders in the USSR have until now regarded plaster as material which was fundamentally useful only for stucco works. In recent years, interest was shown in plaster as material for partitions and sub-flooring; with regard to the application of reinforced plaster elements, when submitted to a flexing test and thereby immediately taking an appreciable weight, none of our builders has made any such attempt as far as is known.

An opinion exists that the introduction of sulphur into plaster composition has a destructive action on a steel fitting, and that the small resistance of plaster to compression and its weak cohesion with the fitting does not guarantee the necessary safety coefficient for elements submitted to a flexing test. With this consideration in mind, our builders declare themselves to be against the use of reinforced plaster.

It is to be noted that foreign builders, who have used reinforced plaster products for many years successfully and on a large scale, have refuted these numerous arguments.

Reinforced plaster between-floor ceilings and coatings are made from monolithic slabs (moulded in place) or from prefabricated slabs (produced in the factories and only assembled in the construction area).

With the production of these and other types, the composition of semihydrous calcined plaster is altered with fine wood shaving in the proportion: 12.5 kg of shaving to 87.5 kg of plaster. The plaster is mixed with the shaving in dry form (preferably in the factory). Short-grained shaving 1.5 mm wide and 25 mm long is taken, and thoroughly dried (preferably from the wood of the coniferous species).

Increasing the heat-insulation and sound-insulation properties of the plaster slabs, the shaving also decreases the tendency of the slabs towards cracking, but does not noticeably lower the fireproof quality of the construction. When mixing plaster, it is recommended that not more than 60 percent water is used.

As usage has shown, plaster does not protect a steel fitting from corrosion while the moisture is being removed from the plaster solution. It is possible that during this period initial corrosion is not dangerous for large rounded fittings and section-shaped iron which have a sufficiently large cross-sectional surface area; however, additional measures are required in the case of reinforcement of thin-steel wires.

With the smaller sizes of wire section, the initial corrosion can cause a noticeable lowering of the safety coefficient of a slab reinforced by such wire. Thin wire (with diameter of 4-5 mm or less) must be protected from initial corrosion by means of galvanization (zinc, lead plating) or staining.

The change in volume of plaster in the process of setting, and the small force of cohesion of the fitting with plaster require the special fastening of the fitting and the other principle of reinforcement of plaster slabs in relation to ferroconcrete.

The fitting of a plaster slab is designed and worked out like a flexible thread, fastened at the supports.

In sketches 1, 2, and 3, details are shown of the reinforcement of a monolithic plaster slab, and, in sketch 4, the process of reinforcement itself. The span of similar large-span slabs may be up to 3 meters; however, with a slab 7.5 cm thick, a span of not more than 2.5 meters is recommended.

Reinforced wire rods pass uninterruptedly through the continuous slab, across all the spans, and are secured at the outer supports.

In the center of the span, the foundation fitting of the slab is fastened with a rod 16 mm in diameter, laid parallel to the girders and intended to hold the foundation fitting in its designed position; apart from that, this rod takes up and transfers to the plaster the vertical component of the tension of the fitting.

Regarding the work of the fitting as that of a flexible tensile thread at the most dangerous moment for the structure, i.e., when a fracture appears in the middle of the span of the slab and over the support, it is not difficult to produce a formula for the determination of the permissible load on the slab. Working out the equation of the balance of forces and observing the symbols used in sketch 5, we get

$$p = \frac{8\sigma fh}{L\sqrt{L^2 + 4h^2}}$$

where p = linear load on the slab (including the natural weight of the latter);

σ = permissable tension on the stretching in the fitting;

f = cross-sectional area of the fitting (per unit of width of the slab);

L = span of slab;

h = distance between centers of gravity of the fitting (sketch 5).

It is necessary to counterbalance the horizontal component of the tension of the fitting at the outer supports (girders). Therefore, the outer supports must possess sufficient rigidity in the horizontal direction and be worked out with a calculation of the aforesaid component. For the increase of horizontal rigidity and supporting power, two outer spans are recommended which link up by a system of rigid supports.

When casting monolithic plaster slabs for coverings, it is possible to employ wood-planed or plywood moulds closely fitted in joints. The mould can be removed 3-4 hours after pouring in the plaster, but is usually removed on the second day.

Up to 20 days are required for the complete drying of the cast of the plaster slab in position; in the meantime, the possible damping of the structure by rain is not dangerous.

One of the chief faults of monolithic plaster coverings is the length of time required for drying; therefore, prefabricated plaster coverings have an advantage over the monolithic plaster coverings.

The principle of construction of prefabricated reinforced slabs is shown in sketch 6; in sketch 7, the laying of roof coverings made from such slabs is depicted. The static scheme of work is for the most part the same for reinforced coverings as with monolithic slabs: consequently, all requirements for fastening the fitting at the supports remain in force, as do those for the horizontal rigidity of the outer girders.

The ends of the fitting, which are freed from the slabs after they are laid, are joined to the supports in pairs, forming a continuous thread, as in the case of the monolithic variation of the slab. The joined ends (for joining, special keys are used) are fitted into the groove left at the time of production of the slabs and are filled in, together with the groove, by plaster solution (which ...).

The fastening of the covering fitting for prefabricated slabs at the outer support is shown in sketch 8. The spans of similar large span prefabricated slabs may be taken as the same as with monolithic slabs, i.e., up to 2-2.5 meters where the thickness of the slab is not less than 7.5 cm.

Somewhat different to the large-span slabs are the so called small-span plaster slabs, which are reinforced with spans of not more than 0.75-0.90 meters.

In view of the fine galvanized wire netting, fittings of the latter type do not require fastenings at the supports, as is done in the case of large-span fittings. With insignificant support reactions and a comparatively large height of slab, the securing of the fitting is sufficiently safely guaranteed by its cohesion with plaster alone.

Slabs may be continuous, with a width of 7.5 cm, or with gaps with a width of 10 cm. After making the junctions between slabs, they are filled with a plaster solution. For convenience of pouring in, bevels are left in the slabs.

The weight of a covering made from similar slabs, together with the roofing materials, is not more than 100 kg per square meter.

With the fixing of the small-span slabs into the between-floor covering, a ceiling can be formed by any means, particularly by fitting a lining of stucco below the slabs.

Of undoubted interest is the extension of coverings and ceilings obtained from so-called plaster boards (planks). In sketch 10, the layout is shown of between-floor ceilings made from such boards, 6.5 cm thick, laid in the form of a floor layer. The ceiling of the covering is made from plaster slabs, 5 cm thick, suspended from beams. The planks are made in lengths of up to 2 meters and can be joined with one another alternately at any place on the span. The weight of such a covering is approximately 125 kgm/sq m., i.e. almost twice as small as wood coverings with sub-floorings and fillings.

In sketch 11, the plaster plank adapted for coverings and ceilings is shown. Just as in the ceiling in sketch 10, the groove is made by a form of plaster cast, so in the slabs in sketch 11 it is made from thin metal in the form of an adapter surrounding the plaster slab on a perimeter. Reinforcing the slab, a fine steel net is secured to the fitted metal adapter. With the fastening of the slab by plaster the metal adapters replace the lateral edges of the mold, reducing it to a minimum.

The metal groove increases the durability of the slabs, makes possible a far greater precision in their production, and guarantees speed of assembly in coverings.

This far-from-complete survey of the technique of the use of plaster in the supporting structures of buildings has been written with the aim of showing the undoubted advantages of reinforced plaster coverings and ceilings over those made of wood (and in many cases also over those made of ferroconcrete), and to arouse the interest of our builders -- both manufacturers and designers -- in plaster as a most valuable material for the construction of buildings.

The use of reinforced plaster ceilings for single and multi-floored buildings, instead of wood ceilings, strongly increases the fireproof and sanitary-hygiene qualities of the buildings.

Use should be found for reinforced plaster slabs not only in the ceilings of industrial buildings being newly constructed, but also in buildings which are being reconstructed (e.g., replacement of wooden roofs) in all cases when the central heating and gas system of the building cannot exercise a harmful influence on the plaster or fitting.

The almost universal occurrence of gypsum, the comparative simplicity of the equipment for its production, the low expenditure of fuel for calcining (the

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calcination of gypsum requires 40-50 kg/ton of material), and the ability to use fuel of any sort makes gypsum one of the most valuable forms of local building material for us.

The development of the plaster industry and the industry of structural plaster components is of particular interest for the nonwooded regions of the USSR, particularly for the regions of Central Asia which are rich in deposits of excellent gypsum and at present use cement and wood imported over long distances.

The speed of setting of plaster, and its important quality of giving off heat during this process, permits the use of plaster structures in low winter temperatures, which is particularly important under building conditions prevalent in our northern regions.

KEY TO SKETCHES

(Not reproduced herein)

Sketch 1 Reinforcement of plaster monolithic covering (central span)
1 - girders of covering; 2 - operating fitting (of wire);
3 - tension distributing rod ($\varnothing \geq 16$ mm

Sketch 2 Detail of fastening of fitting at the outer support (in the case of monolithic slab)
2 - spindle of operating fitting (of wire); 3 and 1 - stay rods of bar iron 5 x 25 mm; 4 - slab of plaster covering;
5 - operating fitting of slab.

Sketch 3 Fastening of fitting at the outer support in the case of monolithic working.

Sketch 4 Assembly of fitting in monolithic plaster covering.

Sketch 5 Statistical scheme of work of fitting (on the appearance of a crack in the center of the span of the slab and over the support).

$$\sin\alpha = \frac{2h}{\sqrt{L^2+4h^2}};\ \cos\alpha = \frac{L}{\sqrt{L^2+4h^2}};\ N = \frac{PL}{4\sin\alpha} =$$

$$= \frac{PL\sqrt{L^2+4h^2}}{4\cdot 2h} = \sigma\cdot f;\ P = \frac{8\sigma\cdot fh}{L\sqrt{L^2+4h^2}}.$$

Sketch 6 Principle of reinforcement of prefabricated large-span slabs.

Sketch 7 Laying of prefabricated slabs during the construction of a roof covering.

Sketch 8 Detail of fastening of fitting at outer support (in the case of prefabricated slab).

Sketch 9 Small-span plaster slabs for ceilings.
(a) Slabs, reinforced by galvanized steel netting;
(b) Prefabricated plaster slabs.

Sketch 10 Between-floor ceiling made of plaster planks.
1 - prefabricated plaster planks 25 x 180 cm; and 6.5 cm thick;
2 - right adapter.

Sketch 11 Plaster plank with metal groove.

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